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Direct Costs of Silvicultural Treatments on National Forests, 1975-78

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Direct Costs of Silvicultural Treatments on National Forests, 1975-78

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RESEARCH SUMMARY

The direct costs of silvicultural treatments was estimated from service contracts awarded on National Forests throughout the United States in 1975-78. The mean direct cost and the Forest Service (USDA) field time spent in the preparation, supervision, and inspection of the silvicultural work were estimated by treatment and forest-type group strata.

Four types of silvicultural treatments, or practices, were studied: site preparation, reforestation, intermediate treatment, and slash disposal. The unit of observation was a single contiguous treatment area, or tract, that may be all or part of the entire service contract. A total of 2,957 observations were received and analyzed from report forms sent to National Forests. Of that total, 307 were discarded because of missing values for critical variables. All results were reported in 1978 dollars.

Cost predictions were developed for nine of the more frequently encountered silvicultural treatment and forest-type group combinations. They express cost per treatment area as a function of treatment and site characteristics. These equations include only those variables that are commonly known or that can be easily estimated before a treatment is carried out.

The mean direct cost of all the practices was $52 per acre, and the mean Forest Service field time was 1 hour per acre treated. Costs varied considerably—even within a treatment and forest-type group stratum. The cost variation is not large enough to yield correspondingly large variations in internal rates of return calculated from the mean treatment cost for the practice and forest-type group stratum. The variation is large enough, however, to require caution when the cost averages are used in the preparation of silvicultural budgets. Unless the composition of treatments planned in the future budget is similar to the program from which the cost averages were derived, the budget could contain substantial errors.

The real treatment costs, that is, cost increases in excess of the inflationary rate, rose roughly 20 percent per year between 1975 and 1977. Since these real cost increases were not the same for all treatments, financial returns may have to be recalculated more frequently than previously thought by using updated cost estimates. The real cost increases are also large enough to consider in the preparation of silvicultural program budgets.

The mean treatment area size was 117 acres. The cost prediction equations indicate that substantial economies relative to scale can be achieved up to treatment area sizes of 75 to 100 acres. The new regulations on cutting area size promulgated by the National Forest Management Act are usually smaller than this. Some savings were apparent when several treatment areas were combined in the same silvicultural service contract, however, which can help offset the diseconomies from treating small tracts. These results indicate then that the smaller treatment areas that are likely to result from implementation of the new cutting area regulations may lead to increases in silvicultural costs by more than 50 percent for some treatments.

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INTRODUCTION

Millions of acres of forest land in the United States undergo silvicultural treatment each year. In 1977, for example, 1.9 million acres were reforested, and 1.3 million acres received intermediate treatment, such as precommercial thinning and release (U.S. Dep. Agric., Forest Serv. 1982). The Forest Service estimates that it would be feasible to treat another 168.2 million acres at a cost of $15.2 billion.

Silvicultural treatments or practices are of four broad types: (a) site preparation for seeding, planting, or natural regeneration, consisting of burning, low-intensity preparation, or high-intensity preparation; (b) reforestation by hand or machine planting, or seeding; (c) intermediate treatment, including precommercial thinning, timber stand improvement, and individual tree or area release by aircraft, hand, or machine; and (d) slash disposal.

Cost estimates are needed at several points in the analysis of silvicultural treatment opportunities. They are particularly important for estimating financial returns because estimates of returns are relatively more sensitive to errors in treatment costs than to errors in timber yield data or stumpage prices (Mills and others 1976). Treatment costs are an early and critical entry in the time stream of costs and returns.

Cost estimates are also needed to prepare budgets for silvicultural programs. In most large land-management agencies, the first budget estimates are prepared 2 to 3 years in advance. Information is needed, therefore, on real cost changes across time, and about the variability of costs among treatment categories.

Cost estimates are important in allocating funds for competing silvicultural projects. By knowing whether cost estimates are comparable and why they vary, the manager can determine the most efficient allocation of available funds. The allocation of cost-share funds for public assistance programs is sometimes based on cost averages for a wide area without much attention to cost variations among individual treatment areas or tracts (Mills and Cain 1978).

Cost estimates and equations for predicting costs have been published from a number of regional and national studies. Predictive equations for site preparation, planting, thinning, and some protection work were developed for the northern Rocky Mountains (Wikstrom and Alley 1967). Data from land-management agencies in Minnesota and Michigan were used to develop predictive equations (Olson and others 1978). To develop such equations for labor-hours and equipment-hours for several treatment categories, data from State records in Indiana, Maine, New York, and Wisconsin were used (Conkin 1971, Hilliker and others 1969). The requirements for labor and equipment must be multiplied by a per-hour cost estimate.

Cost averages were derived for three regions in the South in several studies (Moak and Kucera 1975, Moak and others 1977, Somberg and others 1963, Worrell 1953, Yoho and Fish 1961, Yoho and others 1971). The results suggest that the real cost of some silvicultural treatments rose between 1967 and 1979, and that the real cost of removing undesirable trees chemically and of mechanical site preparation rose faster than the price of southern pine timber.

A nationwide study of silvicultural treatment costs used service contracts awarded on National Forests (Row 1971). Cost prediction equations and cost averages were formulated from that data.

All of these studies generally show that silvicultural treatment costs vary substantially, but that some of the variation can be explained through regression analysis. A more current set of cost estimates is needed, however, especially for making nationwide analyses.

This paper reports estimates of treatment costs for a wide range of silvicultural treatments and forest types in the National Forests for 1975-78. It quantifies the variability in treatment costs, and offers some explanation of the variability. It also documents the considerable economies relative to scale that are possible as tract sizes are increased.

SOURCES OF DATA

The nationwide source for cost data in this study was silvicultural service contracts awarded on National Forest lands. This provided comparability among regions and even among individual cost observations that are available from few other sources. The silvicultural service contracts are awarded to private companies and individuals. Cost data from this source are unencumbered by some of the problems encountered in a public agency's accounting records, especially the difficulty of separating indirect or overhead costs from direct costs. Because the service contracts are also awarded on the basis of competitive bids and contract payment is carefully tied to accomplishment, the costs may be a more accurate estimate of true costs than other data sources would provide.

After pilot testing them on two National Forests in Wyoming and Oregon, we sent the reporting forms and instructions *(fig. 1)* to all National Forests. Forest Supervisors were requested to list all successful contracts awarded and completed in fiscal years 1976 and 1977, including the 1976 transition quarter. The Forests voluntarily also returned forms for contracts completed in fiscal years 1975 and 1978. Observations from these 2 years were added to increase the total number of observations. Of the total observations retained in the analysis, 6 percent were from 1975, 44 percent from 1976, 43 percent from 1977, and 7 percent from 1978 contracts. Because these particular data are not compiled in other places, we know of no way to estimate what percentage of the total number of contracts is represented by the data reported here.

A single service contract is often awarded for several separate tracts. These treatment areas are not always immediately adjacent, but they do usually require the same silvicultural treatment and many are also similar in stand characteristics. To reduce the reporting load, the Forests were asked to (1) separate the multiple treatment areas covered by one contract into groups according to bid value or treatment cost and forest-type similarity; (2) apportion the total contract bid value to each of these separate treatment areas; and (3) complete a single report for a representative treatment area from each group of similar but noncontiguous areas.

The unit of observation then is a single contiguous treatment area or tract that may be all or only a portion of an entire service contract. All of the information reported, such as stand and site characteristics and treatment cost, are for that separate treatment area. The number of multiple treatment areas covered by each contract was reported to test the hypothesis that economies relative to scale could be achieved with an increase in the number of treatment areas covered by one contract.

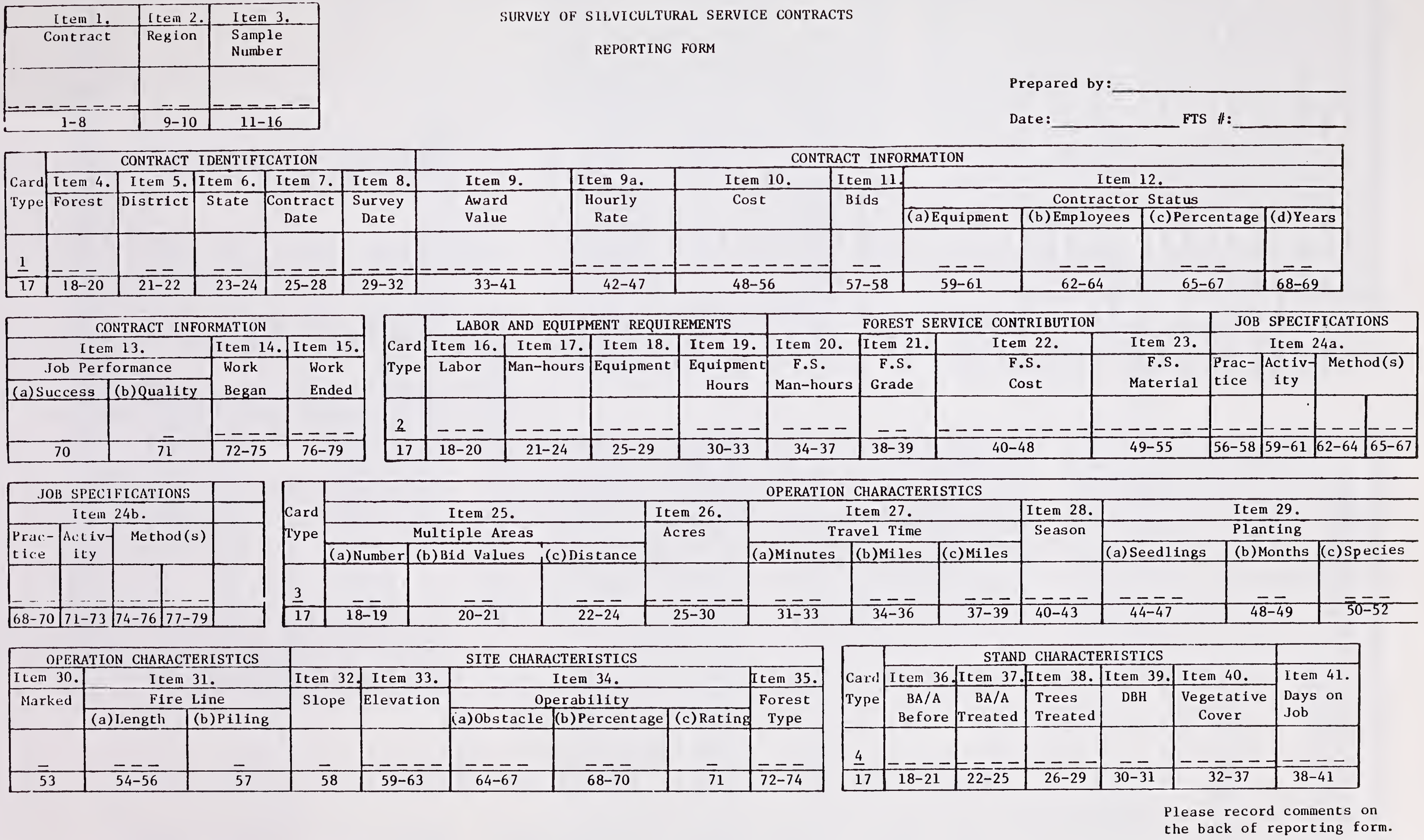
The presence of the multiple treatment areas within a single contract lead to some reporting problems, in particular to the potential for reporting estimates for the whole contract rather than an individual treatment area. The potential for this problem to arise was checked by returning sample reporting forms they had submitted to 18 National Forests. Their review of the forms confirmed that the originally reported cost and acreage estimates almost always corresponded to the entire contract amount rather than to the prorated share appropriate for the representative contiguous treatment area. We adjusted the data by dividing the originally reported acreage and cost by the number of multiple areas reported for the contract.

We received 2,957 observations. Of that total, 307 observations were discarded because of missing values for critical variables, such as treatment cost, or because of illogical codes or values. The 307 discarded observations are assumed to be randomly distributed among the 2,957 observations. Missing values were present in some variables of the 2,650 retained cases:

Variable:	Missing Values
Contract information	
Bids received	507
Contract employees	271
Percent contractor time	384
Contractor-years' experience	393
Duration of contract	19
Forest Service hours	65
Operation characteristics	
Average distance between multiple areas where more than one contiguous area in same contract	84
Seedlings per acre reforestation and site preparation treatments	18
Months since site reforestation and preparation treatments	115
Site characteristics	
Slope	29
Elevation	26
Obstacle class	17
Stand characteristics (site preparation, site preparation and reforestation, and intermediate treatment observations)	
Basal area per acre	812
Trees treated	628
Average d.b.h.	482

Missing values were most frequent in the variables on contractor characteristics and timber stand characteristics. The contractor data came from personal knowledge of National Forest personnel who completed the reporting forms. The timber stand data, such as trees treated per acre, were derived from timber inventories or compartment examinations of the treated area. The large number of missing values in stand characteristic variables indicates the difficulties encountered in matching the contracting and timber inventory data together for the treatment area.

The edited data were transformed in three ways. Slope percentages were set at the midpoint of each of the four reported slope classes. Some of the reporting categories for silvicultural practice, geographic region, and forest type were combined to derive strata with an adequate number of observations. Contractor cost or bid value and Forest Service material cost were converted to 1978 dollars by deflating with the all-commodity wholesale price index. All study results are reported in 1978 dollars.



SURVEY OF SILVICULTURAL SERVICE CONTRACTS

REPORTING FORM

Prepared by:____________________

Date:____________ FTS #:________

Item 1.	Item 2.	Item 3.
Contract	Region	Sample Number
_ _ _ _ _ _ _ _	_ _	_ _ _ _ _ _
1-8	9-10	11-16

	CONTRACT IDENTIFICATION					CONTRACT INFORMATION							
Card Type	Item 4.	Item 5.	Item 6.	Item 7.	Item 8.	Item 9.	Item 9a.	Item 10.	Item 11.	Item 12.			
	Forest	District	State	Contract Date	Survey Date	Award Value	Hourly Rate	Cost	Bids	Contractor Status			
										(a)Equipment	(b)Employees	(c)Percentage	(d)Years
1	_ _ _	_ _	_ _	_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ _	_ _ _ _ _ _	_ _ _ _ _ _ _ _ _	_ _	_ _ _	_ _ _	_ _ _	_ _
17	18-20	21-22	23-24	25-28	29-32	33-41	42-47	48-56	57-58	59-61	62-64	65-67	68-69

CONTRACT INFORMATION			
Item 13.		Item 14.	Item 15.
Job Performance		Work Began	Work Ended
(a)Success	(b)Quality		
	_	_ _ _ _	_ _ _ _
70	71	72-75	76-79

	LABOR AND EQUIPMENT REQUIREMENTS				FOREST SERVICE CONTRIBUTION				JOB SPECIFICATIONS			
Card Type	Item 16.	Item 17.	Item 18.	Item 19.	Item 20.	Item 21.	Item 22.	Item 23.	Item 24a.			
	Labor	Man-hours	Equipment	Equipment Hours	F.S. Man-hours	F.S. Grade	F.S. Cost	F.S. Material	Prac-tice	Activ-ity	Method(s)	
2	_ _ _	_ _ _ _	_ _ _ _ _	_ _ _ _	_ _ _ _	_ _	_ _ _ _ _ _ _ _ _	_ _ _ _ _ _ _	_ _ _	_ _ _	_ _ _	_ _ _
17	18-20	21-24	25-29	30-33	34-37	38-39	40-48	49-55	56-58	59-61	62-64	65-67

JOB SPECIFICATIONS				
Item 24b.				
Prac-tice	Activ-ity	Method(s)		
_ _ _	_ _ _	_ _ _	_ _ _	
68-70	71-73	74-76	77-79	

	OPERATION CHARACTERISTICS										
Card Type	Item 25.			Item 26.	Item 27.			Item 28.	Item 29.		
	Multiple Areas			Acres	Travel Time			Season	Planting		
	(a)Number	(b)Bid Values	(c)Distance		(a)Minutes	(b)Miles	(c)Miles		(a)Seedlings	(b)Months	(c)Species
3	_ _	_ _	_ _ _	_ _ _ _ _ _	_ _ _	_ _ _	_ _ _	_ _ _ _	_ _ _ _	_ _	_ _ _
17	18-19	20-21	22-24	25-30	31-33	34-36	37-39	40-43	44-47	48-49	50-52

OPERATION CHARACTERISTICS			SITE CHARACTERISTICS					
Item 30.	Item 31.		Item 32.	Item 33.	Item 34.			Item 35.
Marked	Fire Line		Slope	Elevation	Operability			Forest Type
	(a)Length	(b)Piling			(a)Obstacle	(b)Percentage	(c)Rating	
_	_ _ _	_	_	_ _ _ _ _	_ _ _ _	_ _ _	_	_ _ _
53	54-56	57	58	59-63	64-67	68-70	71	72-74

	STAND CHARACTERISTICS					
Card Type	Item 36.	Item 37.	Item 38.	Item 39.	Item 40.	Item 41.
	BA/A Before	BA/A Treated	Trees Treated	DBH	Vegetative Cover	Days on Job
4	_ _ _ _	_ _ _ _	_ _ _ _	_ _	_ _ _ _ _ _	_ _ _ _
17	18-21	22-25	26-29	30-31	32-37	38-41

Please record comments on
the back of reporting form.

Figure 1—Sample reporting form asked for information to be entered in numerical code format.

SILVICULTURAL TREATMENTS AND CONTRACTS

Types of Treatment

Forty-one percent of the total acreage treated received a site preparation or a combined site preparation and reforestation treatment. The final data set encompassed 303,000 treated acres. The remaining 59 percent of the acreage was in intermediate treatments, slash disposal, and a few miscellaneous practices.

This slight majority of intermediate treatments and slash disposal is in only partial agreement with the findings of an earlier study that estimated that the acreage of financially viable intermediate treatments far outweighed financially viable reforestation opportunities (U.S. Dep. Agric., Forest Serv. 1973). About one-half of the total acreage of potential National Forest silvicultural opportunities analyzed in that study were reforestation-related treatments, but only 16 percent of the acreage with opportunities that could earn 5 percent or more return were reforestation-related; the other 84 percent were various intermediate treatments.

Only a few of the silvicultural contracts included both a site preparation and reforestation practice (5 percent). Site preparation (18 percent) and reforestation (16 percent) were more often accomplished separately. This separation of treatments may be a result of the different types of equipment and personnel that the contractor needs to accomplish the two tasks. Site preparation is often an equipment-intensive treatment while reforestation is more often labor-intensive. The same contractor may not have the equipment and labor for both jobs. Another reason why the same contract may not specify both jobs is that the National Forests may accomplish one of the two treatments with Forest Service equipment or labor. The site preparation may be contracted, for example, and hand planting may be done by Young Adult Conservation Corp crews. The site preparation and reforestation treatments are also often done at different times of the year because some forms of site preparation, such as site preparation by crushing, are more effective if reforestation is delayed a short period.

The separation of site preparation and reforestation may be efficient, but it does create the potential for a long delay between the two treatments. A delay permits vegetation to regrow, thereby possibly reducing seedling survival. Areas were reforested on the average of 7 months after site preparation—a period short enough to avoid excessive competition in most cases *(table 1).* Twenty-three percent were reforested within 1 month after site preparation and 73 percent were reforested within 8 months of site preparation.

Almost all of the reforestation involved planting. In only a few cases were seedings done. About two-thirds of the site preparation was done for subsequent plantings, and one-third for subsequent natural regeneration.

Most of the intermediate treatments were precommercial thinnings (83 percent). Timber stand improvements (9 percent) and release (8 percent) were minor subpractice categories. The intermediate treatments were apparently most often applied to dense young timber stands. The mean diameter of the trees treated was only 4 inches, and an average of 766 trees per acre was treated. Properly selected and executed, precommercial thinnings can yield substantial economic returns because timber yield increases can be achieved with relatively low treatment costs (U.S. Dep. Agric., Forest Serv. 1973, 1982).

Table 1—*Mean and standard deviation of select variables*

Variable	Unit	Mean	Standard deviation	Observations
Bids received	Number	5.09	3.55	2,143
Contractor time	Percent	60	35.4	2,266
Contractor's experience	Years	7.17	6.52	2,257
Duration of contract	Months	2.57	3.33	2,631
Forest Service time per treatment area	Hours	80	163	2,585
Forest Service time per acre	Hours	1.02	1.14	2,585
Multiple areas	Number	4.23	6.62	2,650
Average distance between multiple areas[1]	Miles	8.53	10.2	1,448
Seedlings per acre[2]	Number	481	234	879
Time since site preparation[2]	Months	7.16	9.75	782
Basal area per acre[3]	Inches	41.9	45.7	998
Trees treated[3]	Number	766	999	1,182
Average d.b.h.[3]	Inches	3.70	2.48	1,328

[1] Distance between areas in cases where more than one contiguous area was in the same contract.

[2] Computed from observations on reforestation and site preparation and reforestation.

[3] Computed from observations on site preparation, site preparation and reforestation, and intermediate treatment.

Size of Treatment Areas

The mean size of a separate contiguous treatment area was 117 acres *(table 2).* The mean size of the slash disposal treatment was 250 acres, and the mean size for the other categories ranged from 70 to 161 acres. Mean treatment area size varied substantially from one strata to another, but there was even more variability within the strata. The mean size for Douglas-fir site preparation, for example, was 93 acres and the mean for ponderosa and white pine site preparation was 153 acres. The standard deviations were 131 acres and 194 acres, respectively, greater than the mean in both strata.

The mean size of these treatment areas was considerably larger than the acreage of areas treated in the Forestry Incentives Program (FIP)—a Federal cost-sharing program for nonindustrial private forest landowners. The mean FIP tract size in 1974 for planting practices was 15

Table 2—*Separate contiguous treatment areas and mean direct costs of silvicultural practices, by forest-type group*

Silvicultural practice	Treatment area		Mean direct cost (1978 dollars)	
	No.	Mean avg. size (acres)	Per acre	Per tract
Northern conifers (includes red-white-jack pine and spruce-fir)				
Site preparation	15	25 (8)[1]	37 (23)	849 (560)
Reforestation	65	30 (30)	50 (18)	1368 (1042)
Site preparation and reforestation	—	—	—	—
Intermediate[2]	22	55 (40)	19 (12)	952 (819)
Slash disposal	—	—	—	—
All practices	109	36 (35)	41 (22)	1178 (939)
Southern pines (includes longleaf-slash pine, loblolly-shortleaf pine, and oak-pine)				
Site preparation	126	77 (114)	46 (18)	3217 (3367)
Reforestation	74	67 (61)	37 (11)	2414 (1870)
Site preparation and reforestation	—	—	—	—
Intermediate[2]	28	89 (59)	37 (17)	3350 (3462)
Slash disposal	—	—	—	—
All practices	232	76 (98)	42 (17)	3010 (2994)
Central hardwoods (includes oak-hickory, oak-gum-cypress, and elm-ash-cottonwood)				
Site preparation	68	28 (21)	47 (26)	1520 (2357)
Reforestation	—	—	—	—
Site preparation and reforestation	—	—	—	—
Intermediate[2]	—	—	—	—
Slash disposal	—	—	—	—
All practices	77	32 (30)	45 (25)	1498 (2237)
Northern hardwoods (includes maple-beech-birch, and aspen-birch)				
Site preparation	86	52 (40)	20 (17)	850 (691)
Reforestation	46	26 (12)	57 (24)	1418 (920)
Site preparation and reforestation	—	—	—	—
Intermediate[2]	33	71 (78)	18 (10)	1090 (1072)
Slash disposal	—	—	—	—
All practices	167	48 (48)	30 (26)	1072 (892)
Douglas-fir				
Site preparation	92	93 (131)	63 (48)	4412 (4574)
Reforestation	251	65 (80)	75 (29)	4815 (6527)
Site preparation and reforestation	55	60 (61)	91 (50)	4999 (5969)
Intermediate[2]	230	85 (105)	53 (31)	3761 (4650)
Slash disposal	13	81 (89)	99 (93)	4650 (4625)
All practices	651	77 (98)	67 (39)	4405 (5558)
Ponderosa pine and white pine				
Site preparation	102	153 (194)	48 (30)	5954 (7286)
Reforestation	130	102 (138)	73 (31)	7633 (10350)
Site preparation and reforestation	58	95 (100)	96 (54)	8028 (9193)
Intermediate[2]	422	268 (341)	32 (23)	6242 (7577)
Slash disposal	60	331 (442)	29 (25)	6222 (6153)
All practices	780	215 (305)	45 (36)	6535 (8083)
Mixed spruce (includes fir-spruce, hemlock-sitka spruce, and larch)				
Site preparation	76	101 (104)	61 (40)	4959 (4695)
Reforestation	86	85 (137)	66 (25)	5656 (8882)
Site preparation and reforestation	14	80 (142)	77 (41)	4975 (7587)
Intermediate[2]	110	97 (105)	66 (32)	5309 (6027)
Slash disposal	11	124 (140)	44 (39)	5145 (7928)
All practices	300	99 (131)	63 (34)	5301 (6775)
Lodgepole pine				
Site preparation	41	89 (124)	42 (17)	3431 (4840)
Reforestation	24	85 (103)	71 (28)	5358 (5847)
Site preparation and reforestation	28	121 (90)	53 (22)	6318 (6475)
Intermediate[2]	104	54 (25)	56 (25)	3020 (4723)
Slash disposal	—	—	—	—
All practices	204	74 (93)	55 (26)	3821 (5200)
All forest types (cases for all forest-types, including categories not shown)				
Site preparation	630	88 (126)	47 (34)	3579 (4714)
Reforestation	702	70 (101)	65 (29)	4614 (7165)
Site preparation and reforestation	174	86 (96)	81 (49)	6028 (7292)
Intermediate[2]	964	161 (254)	43 (29)	4754 (6303)
Slash disposal	91	250 (381)	44 (51)	4492 (4988)
All practices	2590	117 (198)	52 (35)	4536 (6281)

[1] Standard deviations are shown in parentheses.

[2] Includes control of undesirable vegetation, clearing, individual tree or area release, and precommercial thinning.

acres and for timber stand improvement was 18 acres (Mills 1976). The mean FIP tract sizes in 1978 were roughly twice as large as in 1974: 39 acres for site preparation, 33 acres for planting, and 34 acres for timber stand improvement. Although larger than in 1974, the 1978 FIP tract sizes are only about one-fourth as large as the contiguous treated acreage in the 1975-78 National Forest silvicultural contracts.

The mean tract sizes for the silvicultural contracts is also larger than the maximum acreage of cutting blocks specified in the regulations established to implement the National Forest Management Act (U.S. Dep. Agric., Forest Serv. 1979). The maximum cutting block size varies from 40 to 100 acres, depending on which forest type is involved.

There is no implication here that the new regulations were violated. These silvicultural practices were completed before the new regulations were issued and some of the treatments result from shelterwood harvests are not constrained by the clearcutting regulations. Also, the silvicultural practices and cutting blocks do not always coincide. The practices are sometimes applied to wildfire areas, for example. This contrast in acreage does, however, give some indication of the potential effect of the new regulations on the tract size of silvicultural treatments in the future.

The mean number of multiple treatment areas in each contract was 4.3, but the number of such areas varied from one contract to another *(table 1).* The mean number of multiple areas in most of the treatment categories ranged from 3.0 to 3.9. The number of multiple areas for the reforestation treatment observations was 6.2, about twice as many as the other treatment categories.

Characteristics of Contractors

Three types of information were collected about the contractors themselves: number of employees, percentage of time spent on silvicultural contracts, and the number of years of silvicultural treatment experience. The mean number of employees for cases in most categories ranged from six to nine. The mean number of contractor employees for the reforestation treatment was 28, considerably higher than the mean number for other practices. One explanation for this difference is that much of the tree planting, particularly in the West, is on terrain too steep and rugged for machine planting. Hand planting is more common. The other practices make relatively more use of equipment.

Using a simple statistical test to compare two means, we found a statistically significant relationship between the mean direct cost per acre and the number of employees. The mean direct cost per acre was $40 for observations where a contractor had no employees. The mean cost was $62 per acre for areas treated by contractors with seven or eight employees. The mean cost for treatments by contractors with more than 18 employees was $73 per acre. The $40 was significantly lower than the $62 cost at the 95 percent significance level and the $62 cost was significantly lower than the $73 cost in turn.

The contractors spent an average of 61 percent of their time working on silvicultural treatment. The mean years of experience in performing silvicultural treatment was 7 years. Over half (56 percent) of the contractors had 5 years of experience or less, and 18 percent had over 10 years of experience in silvicultural treatment activities. The mean duration of the contracted work was 2.6 months.

ESTIMATES OF TREATMENT COSTS

To estimate direct cost, we added the cost of Forest Service materials used in the treatment to the contract cost. The cost of Forest Service time spent in the field preparation, inspection, and supervision of the treatment was not added to the direct cost estimate, although some portion of this time could logically be labeled direct cost.

The cost of Forest Service materials provided for the treatment was only a small percentage of the total direct cost for site preparation (4 percent), intermediate treatments (5 percent), and slash disposal (2 percent). The materials provided were usually fuel and lubrication, handtools, and machinery. The cost of materials for reforestation was a higher percentage of the direct cost (34 percent) as was the cost of materials for the combined site preparation and reforestation practice (17 percent). Material contributions in these treatments were predominantly tree seedlings.

The mean costs for various treatments were *(table 3):*

Treatment:	Cost per acre
	Dollars
Site preparation	47
Intermediate treatment	43
Slash disposal	44
Reforestation	65
Site preparation and reforestation	81

The mean cost of combined site preparation and reforestation was $31 per acre less than the summed cost of the separate site preparation and reforestation practices. This

Table 3—*Separate contiguous treatment areas and mean direct costs of silvicultural practices, by Forest Service Regions*

Silvicultural practice	Treatment area		Mean direct cost (1978 dollars)	
	No.	Mean avg. size (acres)	Per acre	Per tract
Northern (R-1)				
Site preparation	94	92 (104)	52 (37)	3957 (4465)
Reforestation	63	66 (72)	68 (25)	4701 (7278)
Site preparation and reforestation	25	83 (124)	50 (21)	3698 (5872)
Intermediate[2]	152	56 (63)	68 (31)	3617 (4172)
Slash disposal	18	71 (82)	56 (45)	3007 (2990)
All practices	358	72 (88)	62 (33)	3914 (5005)
Rocky Mountain (R-2), Southwestern (R-3), and Intermountain (R-4)				
Site preparation	36	112 (109)	39 (23)	3632 (3110)
Reforestation	66	118 (98)	94 (31)	10963 (9635)
Site preparation and reforestation	78	94 (86)	104 (56)	8330 (9059)
Intermediate[2]	270	313 (387)	33 (20)	6965 (7950)
Slash disposal	18	567 (705)	61 (89)	9748 (8588)
All practices	469	245 (351)	54 (46)	7604 (8333)
Pacific Southwest (R-5)				
Site preparation	101	162 (200)	57 (34)	6585 (5536)
Reforestation	71	102 (111)	53 (20)	5327 (6092)
Site preparation and reforestation	22	87 (103)	71 (24)	5233 (5394)
Intermediate[2]	161	123 (177)	47 (29)	4157 (5060)
Slash disposal	18	236 (201)	29 (17)	5747 (5048)
All practices	380	132 (172)	51 (46)	5143 (5443)
Pacific Northwest (R-6), westside				
Site preparation	60	79 (84)	68 (55)	4245 (4136)
Reforestation	247	64 (104)	75 (28)	4553 (6938)
Site preparation and reforestation	32	75 (77)	76 (42)	4655 (4098)
Intermediate[2]	169	92 (117)	51 (31)	3839 (4976)
Slash disposal	22	205 (217)	43 (42)	4712 (4017)
All practices	537	81 (115)	65 (36)	4301 (5806)
Pacific Northwest (R-6), eastside				
Site preparation	40	128 (175)	48 (32)	5971 (9603)
Reforestation	53	109 (184)	66 (29)	6991 (11687)
Site preparation and reforestation	4	24 (14)	51 (18)	1121 (458)
Intermediate[2]	123	166 (182)	32 (25)	5286 (7627)
Slash disposal	15	168 (140)	28 (24)	4810 (6501)
All practices	237	145 (179)	42 (30)	5677 (8883)
Southern (R-8)				
Site preparation	145	71 (108)	49 (22)	3150 (3438)
Reforestation	71	69 (61)	37 (11)	2476 (1866)
Site preparation and reforestation	—	—	—	—
Intermediate[2]	28	90 (58)	38 (16)	3439 (3406)
Slash disposal	—	—	—	—
All practices	248	74 (95)	45 (20)	3021 (3069)
Eastern (R-9)				
Site preparation	154	40 (34)	27 (19)	888 (770)
Reforestation	131	27 (22)	51 (20)	1300 (969)
Site preparation and reforestation	9	65 (71)	40 (20)	1966 (1771)
Intermediate[2]	59	67 (66)	18 (10)	1068 (983)
Slash disposal	—	—	—	—
All practices	359	41 (42)	35 (23)	1104 (946)
Regions R-1 to R-9				
Site preparation	630	88 (126)	47 (34)	3579 (4174)
Reforestation	702	70 (101)	65 (29)	4614 (7165)
Site preparation and reforestation	174	86 (96)	81 (49)	6028 (7292)
Intermediate[2]	964	161 (254)	43 (29)	4754 (6303)
Slash disposal	91	205 (381)	44 (51)	5592 (5988)
All practices	2590	117 (198)	52 (35)	4536 (6281)

[1] Standard deviations are shown in parentheses.

[2] Includes control of undesirable vegetation, clearing, individual tree or area release, and precommercial thinning.

difference may be due to differences in the intensity or difficulty of the site preparation in the combined treatment versus that in the separate treatments. Perhaps only easy cases involving both treatments at once were contracted. Economies may also be achieved by doing the combined treatment at one time.

The mean treatment costs per acre derived from the silvicultural service contracts were roughly comparable with the 1978 treatment cost of practices in the Forestry Incentives Program. The costs per acre were similar even though the total acreage of the service contract practices were considerably larger than the acreage of the FIP practices. The treatment costs per acre in the 1978 FIP program were $55 for site preparation, $72 for reforestation, and $31 for intermediate treatments.

Variations in Cost

While variation in treatment costs is often not visible when other methods are used to collect silvicultural cost estimates, variation exists in the population nonetheless. The large variation in treatment costs found here has important implications for some uses of cost data, but is not overly important for other uses *(table 4).*

The high variation is significant when cost averages are used in preparing budgets for silvicultural programs. If broad resolution cost averages are used, the estimates of the acreage that can be treated with a given budget could contain substantial errors unless silvicultural treatments for the budgeting year are the same as those in the year from which the broad average was derived. The actual number of acres treated could then differ substantially from the planned acres treated.

The cost variation found in this study is not too high to hamper seriously financial return analysis of silvicultural treatment opportunities. Mills and others (1976) estimated the sensitivity of internal rate of return to variations in treatment cost. They calculated the percentage reduction in treatment cost required to raise the internal rate of return by 1 percentage point of interest. In the four Douglas-fir site preparation and reforestation cases they studied, for example, the treatment cost was reduced by 52 percent before the estimated return rose by 1 percent of interest.

The standard deviation of the Douglas-fir site preparation and reforestation cases in this study was 56 percent of the mean cost. Therefore, roughly one-sixth of the Douglas-fir investments have an internal rate of return at least 1 percentage point above the return estimated using the mean treatment cost for the strata. Although the conclusion varies by practice and forest type, a comparison of the cost variation in this study and the sensitivity analysis by Mills and others (1976) suggests that something less than 20 percent of the investments in each strata would have an actual internal rate of return that differed by more than 1 percent of interest from the return estimated using the mean cost for the strata.

Increases in Real Cost

From 1975 to 1977, the mean cost rose by $8 per year or roughly 20 percent per acre per year *(fig. 2).* This cost difference between years was statistically significant at the 95 percent level. The mean cost increased from $40 per acre in 1975 to $48 per acre in 1976 and to $56 per acre in 1977. The mean cost for 1978 was the same as in 1977, partially because the 1978 bids were awarded using rates established in 1977. The greatest increase occurred in the real cost of the reforestation practice. Its cost rose from $55 per acre in 1975 to $91 per acre in 1978.

Since the practice and forest-type group composition of the silvicultural service contract program was similar for the several years, change in practice composition was probably not the cause for the real cost change. The increased emphasis toward nontimber management objectives on National Forest lands affects the way silvicultural treatments are performed, however, so that nontimber emphasis may have contributed to the cost increase. The actual intensity of the treatments themselves, such as the

Table 4—*Mean direct cost per acre, by silvicultural practice and forest-type group (1978 dollars)*[1]

Forest type group	Silvicultural practices					
	Site preparation	Reforestation	Site preparation and reforestation	Intermediate treatment	Slash disposal	All practices
	Dollars per acre					
Northern conifers	37 (23)[1]	50 (18)	—	19 (12)	—	41 (22)
Southern pines	46 (18)	37 (11)	—	37 (17)	—	42 (17)
Central hardwoods	47 (26)	—	—	—	—	45 (25)
Northern hardwoods	20 (17)	57 (24)	—	18 (10)	—	30 (26)
Douglas-fir	63 (48)	75 (29)	91 (50)	53 (31)	99 (93)	67 (39)
Ponderosa pine and white pine	48 (30)	73 (31)	96 (54)	32 (23)	29 (25)	45 (36)
Mixed spruce	61 (40)	66 (25)	77 (41)	66 (32)	44 (39)	63 (34)
Lodgepole pines	43 (17)	71 (28)	53 (22)	56 (25)	—	55 (26)
All forest types	47 (34)	65 (29)	81 (49)	43 (29)	44 (51)	52 (35)

[1] Values in parentheses are standard deviations.

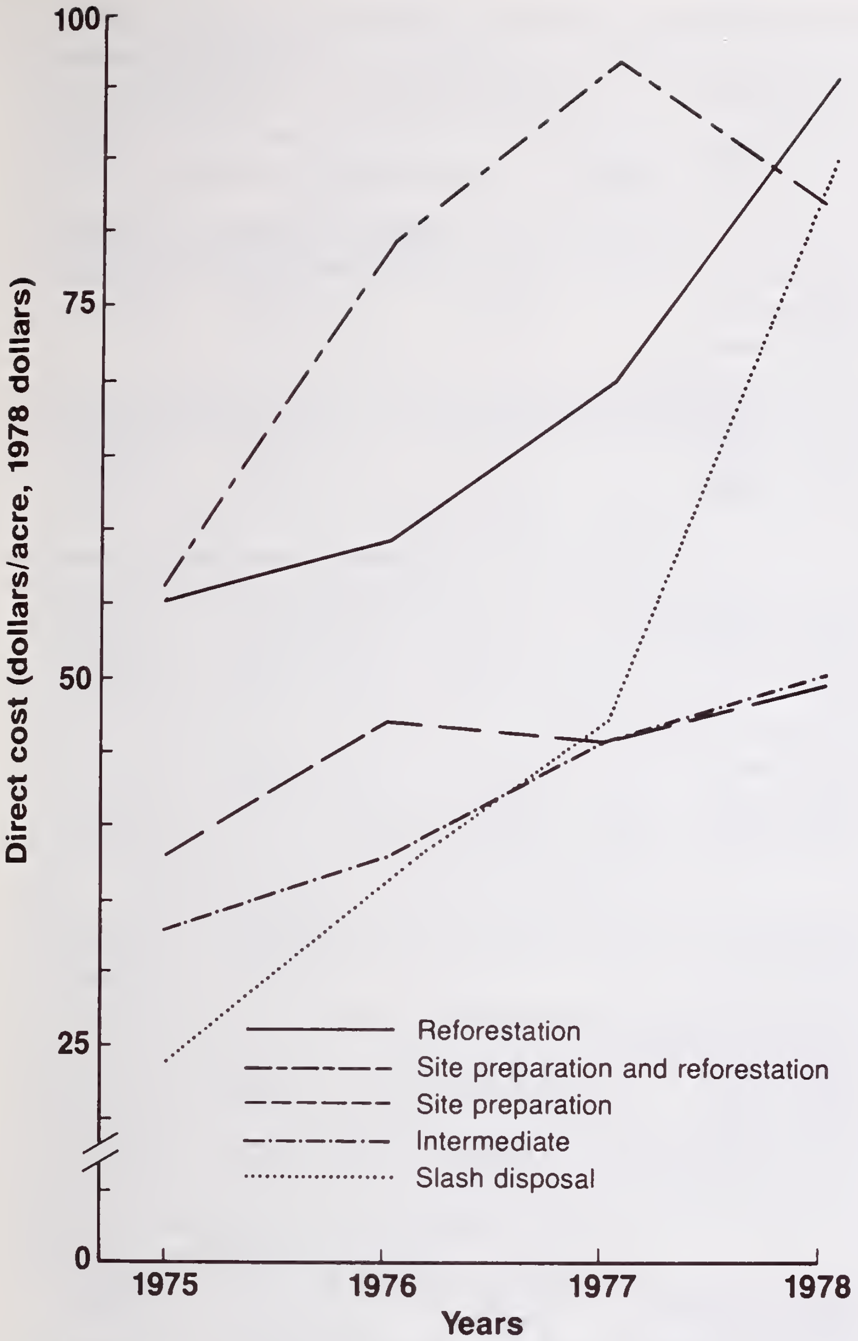


Figure 2—Real treatment costs per acre rose from 1975 through 1978 for almost all treatments.

intensity of site preparation, may also be increasing with resultant cost increases. A sharpening of contract specifications and contract administration in response to the regulations issued from the National Forest Management Act of 1976 may also be a cause of the cost increase. No corresponding data on treatment success, such as percentage seedling survival, were collected for this study.

Moak and others (1980) also found a real cost increase for silvicultural treatments in the South. They concluded that increased energy costs were pushing up the real cost of heavily mechanized treatments, and that real labor cost increases were also a factor.

Whatever the cause of the increases in real treatment costs, they must be considered in preparing budgets for silvicultural programs. Most public agencies prepare their first budget estimates 2 or 3 years before the actual treatment. Assumptions about real cost changes as well as inflationary changes should be woven into those budget requests. If the real cost increases continue into the future, the cost estimates must be updated more frequently than has generally been common in the past. Increasing real costs also influence how long financial return results from silvicultural treatment case studies are useful. The real cost changes were not uniform, by treatments, either in this study or in the one by Moak and others (1980). The relative financial returns between practice categories, therefore, may change over time as well as the absolute return on all practices.

Costs by Treatment Method

Cost per acre was related to the method used to accomplish the treatment. The detailed treatment methods reported in the original data were grouped into two or three broader method categories for each practice. The mean costs per acre were then calculated for each treatment method.

Burning was the lowest cost method of site preparation *(table 5).* A high intensity site preparation accomplished with heavy equipment was more costly than a low intensity of treatment. The direct cost per acre for site preparation was higher in the West than in the East.

Reforestation by hand was more costly than reforestation by machine in the East, consistent with the results reported by Moak and others (1980). On the other hand, in the West, the machine method of reforestation was the more costly. This difference may be related to the type of equipment used to machine plant on the generally more rugged western sites and the presence of more logging slash than is usually encountered in the East.

Intermediate treatments accomplished with aircraft, such as aerial application of herbicides, were much less costly than machine or hand methods. The machine methods of intermediate treatment were more costly than hand methods in the West, but the reverse was true in the East. Whether a hand or machine method is used is a function of the timber and nontimber objectives as well as the per acre cost.

Table 5—*Mean direct cost per acre, by treatment, method, and region (1978 dollars)*[1]

Treatment and method	East[2]	West[3]
	Dollars per acre	
Site preparation:		
Burn	—	21 (2)
Low intensity preparation	44 (17)	51 (31)
High intensity preparation	49 (23)	60 (37)
Reforestation:		
Hand	47 (16)	72 (29)
Machine	40 (27)	81 (31)
Intermediate treatment:		
Aircraft	12 (4)	16 (7)
Hand	25 (16)	46 (29)
Machine	22 (12)	57 (38)

[1] Values in parentheses are standard deviations.

[2] East includes Southern (R-8) and Eastern (R-9) Regions.

[3] West includes Northern (R-1), Rocky Mountain (R-2), Southwestern (R-3), Intermountain (R-4), Pacific Southwest (R-5), and Pacific Northwest (R-6) Regions.

Table 6—*Mean Forest Service person hours by silvicultural practice and forest-type group*

Silvicultural practice	Treatment area	Mean Forest Service person-hours	
		Per acre	Per tract
	Northern conifers (includes red-white-jack pine and spruce-fir		
Site preparation	15	0.32 (0.47)[1]	8 (15)
Reforestation	65	.71 (.80)	19 (28)
Site preparation and reforestation	—	—	—
Intermediate[2]	22	.52 (.40)	27 (32)
Slash disposal	—	—	—
All practices	108	.64 (.71)	21 (31)
	Southern pines (includes longleaf-slash pine, loblolly-shortleaf pine, and oak-pine)		
Site preparation	124	.47 (.45)	28 (35)
Reforestation	72	.56 (.73)	27 (28)
Site preparation and reforestation	—	—	—
Intermediate[2]	27	.56 (.54)	43 (43)
Slash disposal	—	—	—
All practices	227	.51 (.56)	29 (33)
	Central hardwoods (includes oak-hickory, oak-gum-cypress, and elm-ash-cottonwood)		
Site preparation	68	.78 (.62)	22 (26)
Reforestation	—	—	—
Site preparation and reforestation	—	—	—
Intermediate[2]	—	—	—
Slash disposal	—	—	—
All practices	77	.80 (.64)	25 (38)
	Northern hardwoods (includes maple-beech-birch, and aspen-birch)		
Site preparation	85	.59 (.78)	25 (42)
Reforestation	44	1.07 (1.28)	23 (26)
Site preparation and reforestation	—	—	—
Intermediate[2]	33	1.29 (1.06)	79 (82)
Slash disposal	—	—	—
All practices	164	.87 (1.03)	35 (54)
	Douglas-fir		
Site preparation	92	1.43 (1.32)	108 (170)
Reforestation	250	1.28 (1.13)	86 (182)
Site preparation and reforestation	54	1.72 (1.38)	100 (151)
Intermediate[2]	228	1.13 (1.14)	75 (123)
Slash disposal	13	1.26 (1.68)	203 (545)
All practices	647	1.28 (1.20)	88 (174)
	Ponderosa pine and white pine		
Site preparation	101	.89 (1.23)	82 (137)
Reforestation	128	1.52 (1.37)	124 (189)
Site preparation and reforestation	55	1.69 (1.55)	124 (157)
Intermediate[2]	413	.73 (.87)	119 (246)
Slash disposal	58	.54 (1.07)	84 (105)
All practices	762	.94 (1.14)	112 (210)
	Mixed spruce (includes fir-spruce, hemlock-sitka spruce, and larch)		
Site preparation	75	1.03 (1.12)	68 (58)
Reforestation	85	1.61 (1.48)	139 (283)
Site preparation and reforestation	14	1.78 (1.70)	82 (62)
Intermediate[2]	110	1.22 (1.22)	80 (92)
Slash disposal	11	.72 (.78)	47 (40)
All practices	298	1.29 (1.31)	93 (167)
	Lodgepole pine		
Site preparation	41	.54 (.39)	39 (81)
Reforestation	24	1.40 (.98)	104 (143)
Site preparation and reforestation	28	.97 (1.11)	89 (140)
Intermediate[2]	102	1.37 (1.36)	66 (112)
Slash disposal	—	—	—
All practices	202	1.19 (1.25)	68 (115)
	All forest types (cases for all forest-types, including categories not shown)		
Site preparation	622	.80 (.97)	52 (99)
Reforestation	690	1.22 (1.21)	83 (177)
Site preparation and reforestation	168	1.46 (1.43)	97 (140)
Intermediate[2]	949	.97 (1.07)	91 (183)
Slash disposal	89	.81 (1.35)	96 (224)
All practices	2545	1.02 (1.14)	80 (163)

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[1] Standard deviations are shown in parentheses.

[2] Includes control of undesirable vegetation, clearing, individual tree or area release, and precommercial thinning.

The mean costs per acre by practice and method were consistently higher in the West than in the East *(table 5)*. The difference was least for aircraft methods of intermediate treatments where tree size and ruggedness of terrain have less of an effect on costs. Strong patterns of geographic cost differences are not apparent for finer regional stratification within the East and West *(table 3)*.

Time Spent on Contracted Work

The mean Forest Service time spent on the field preparation, supervision, and inspection of the silvicultural work was 1.02 hours per acre treated and 80 hours per treatment area *(table 6)*. The mean time spent was greatest for the combined site preparation and reforestation treatment (1.46 hours per acre). This time estimate included only field time and excludes management time spent in the District Ranger's Office, the Forest Supervisor's Office, and the Forest Service Regional Office. Some of the field time could logically be categorized as a direct cost, although it was not included in the direct cost estimates reported here.

The grades of the Forest Service employees who did the field work ranged from GS-3 to GS-11, but the grades most often reported were from GS-5 to GS-9. The approximate 1978 hourly salary, plus benefits, for these grades ranged from $5.40 to $8.96. The salary cost of the field time spent was 10 to 20 percent as much as the direct cost for the contractor and Forest Service materials.

We hypothesized that the Forest Service field time spent per acre treated would decline as the size of the treatment area increased. The mean field time per acre generally decreased as the treatment area size increased, consistent with the hypothesis of economies to scale, but the relationship was not statistically significant. The mean Forest Service time on less than 50-acre treatment areas was 1.44 hours per acre, 0.84 hours per acre for 200- to 250-acre treatment areas, and 0.54 hours per acre for treatment areas over 450 acres.

EQUATIONS PREDICTING COST

Cost prediction equations that express treatment cost per treatment area as a function of practice and site characteristics were developed for nine silvicultural practices and forest-type group strata. The equations include only those variables that are commonly known or can be easily estimated before a treatment is actually made.

A screening procedure that included all observations was used to determine which variables were most significant. Once the most significant variables were identified, only observations that had no missing values in those variables were used to estimate the final equation.

The prediction equations for each stratum were developed through a multistep procedure. First, the simple correlations between the independent variables were estimated and an all-possible value covariance matrix was calculated. Independent variables with simple correlations of 0.80 or greater were identified and one of the two correlated variables was excluded from further analysis in that stratum.

Second, the all-possible values covariance matrix, rather than the actual data, was entered into the BMD P9R subroutine and all-possible regression equations were estimated (Dixon and Brown 1979). The equation having the lowest value for Mallow's C_p was selected from this set of all-possible regressions. Mallow's C_p is an index of unexplained variation rather than the variation explained. The variables included in the selected equation were noted.

Third, a regression equation was again derived with the P9R routine but this time using only observations that were complete in all variables included in the selected regression equation of the previous step. The significance of the final equation was sometimes higher and sometimes lower than the regression derived from the covariance matrix, but the change was minor.

The statistical significance of the regression equations for direct cost of the treatment area was only moderate. The adjusted R^2's were generally between 0.60 and 0.85 *(table 7)*. The standard error of the estimate was 29 to 89 percent of the mean cost per treatment area. The moderate significance levels were not surprising given the high standard deviations about the mean costs.

The relatively low significance levels and high cost variances for the equations are similar to those found in earlier studies. Gonzalez-Caban (1984), Loveless and others (1982), and McKetta and Gonzalez-Caban (1984), for example, found similarly high variances and moderate to low explanatory power in studies of the cost of mopup after wildfires, fuel treatments for fire hazard reduction, and prescribed burning for wildlife management.

The inability of these regression studies to explain a larger portion of the cost variance with the most com-

Table 7—*Cost prediction equations for direct cost per treatment area, by forest-type group*

Treatment and forest-type group	Equation[1]	Adjusted R^2	Mallow's $\hat{C}_p$	Standard error	Standard error percent[2]
Site Preparation:					
Southern pine	$D\$ = 846.02 + 22.83\,AC - 79.78\,MA + 213.61\,DBH$ (525.51) (1.71) (40.01) (87.16)	0.65	4.00	2136.	63.80
Douglas fir	$D\$ = 3647.15 + 18.49\,AC - 290.25\,MA$ (646.92) (3.02) (114.21)	.38	2.58	3598.	81.58
Ponderosa/white pine	$D\$ = 5937.93 + 26.69\,AC - 98.58\,BIDS - 212.46\,MA - 0.68\,ELEV$ (2158.01) (2.73) (150.95) (115.99) (0.36)	.58	5.00	4832.	80.20
Reforestation:					
Northern conifer	$D\$ = -228.45 + 32.26\,AC + 51.13\,BIDS + 28.38\,SL - 260.42\,OB + 0.48\,S/AC$ (321.85) (2.25) (14.10) (28.38) (163.57) (0.08)	.81	6.00	472.	33.99
Southern pine	$D\$ = 1022.60 + 26.74\,AC - 54.49\,MA + 31.23\,SL - 0.55\,ELEV$ (265.75) (1.40) (14.59) (13.98) (0.19)	.86	5.00	694.	28.81
Douglas fir	$D\$ = 556.29 + 76.08\,AC - 35.06\,AVD - 0.13\,ELEV$ (497.65) (1.71) (17.89) (0.12)	.90	4.00	2131.	43.42
Ponderosa/white pine	$D\$ = -5131.57 + 63.63\,AC - 317.46\,BIDS + 1.28\,ELEV + 938.52\,OB$ (1820.02) (2.82) (155.19) (0.31) (825.39))	.84	5.00	4198.	55.74
Intermediate[3] treatments:					
Douglas-fir	$D\$ = 1640.86 + 29.25\,AC - 60.68\,MA$ (340.84) (2.15) (23.51)	.49	5.01	3318.	88.23
Ponderosa/white pine	$D\$ = 1980.48 + 17.13\,AC - 107.17\,BIDS - 99.38\,MA + 29.08\,SL$ (551.60) (.71) (58.26) (16.10)	.63	5.00	4377.	74.32

[1] Values in parentheses are standard errors of the coefficients.

\$D	Direct cost per tract (1978 dollars)
BIDS	Bids received
MA	Multiple areas
AVD	Average distance between multiple areas (miles)
AC	Acres treated
S/AC	Seedlings per acre (1,000's of seedlings)
SL	Slope (percent)
ELEV	Elevation (1,000's of feet)
OB	Obstacle class (0: no obstacle, 1: obstacle present)
DBH	Average d.b.h. (inches) of treated trees

[2] Standard error of equation as a percent of the mean value for the dependent variable.

[3] Includes control of undesirable vegetation, clearing, individual tree or area release, and precommercial thinning.

monly hypothesized site and treatment variables and the presence of the high cost variance may itself be an important finding. One hypothesis is that the objectives and proficiency of the manager could be the source of the unexplained cost variation. Loveless and others (1982), for example, found that the manager's history of escaped prescribed burns was a significant variable in the explanation of prescribed burning costs. If factors under the manager's control are having a substantial impact on cost and if those factors are not materially affecting the success of the treatment, there may be a need to more carefully specify treatment standards and for sharing the expertise of the more qualified managers.

Because of the manner in which the equations were derived and the presence of residual collinearity among the independent variables, the equations should be used in their entirety without undue concern about the coefficients for individual variables. Because of the consistency of their coefficients among the nine equations and the management implications of the results, only two variables will be discussed separately: acreage of the treatment area and number of multiple treatment areas in the same contract.

We hypothesized that there are sizable economies to scale in silvicultural treatments. These economies are most clearly demonstrated by a reduction in direct treatment cost per acre when the size of the treatment area is increased.

Row (1973) found significant economies to scale in his regression analysis of silvicultural service contracts on National Forest lands. His estimates of treatment cost per acre declined as the size of the area increased and as the number of multiple areas in the same contract increased.

Combining estimates of economies relative to scale in both treatment cost and stumpage price, Row (1978) found a measurable difference in the financial return of silvicultural treatments from one treatment area size to another.

The acreage variable is present in all regression equations, and all but one equation produces results that support the economies-to-scale hypothesis. The economies to scale was studied by holding the value of all variables except treatment area acreage constant at their respective means. The value of the acreage variable was then divided into increments from 25 to 475 acres at 50-acre intervals. The corresponding cost per acre was calculated from the estimated total cost for the treatment area by dividing by acreage. Although the equations for direct cost per treatment area are linear with respect to acreage, they are not necessarily linear in cost per acre.

The economies to scale were substantial in the site preparation and intermediate treatment equations up to treatment area sizes of 100 to 150 acres *(figs. 3, 4, 5, and 6)*. The economies probably derive from the high fixed cost of transporting equipment to and from the treatment site.

The economies to scale in the reforestation equation, on the other hand, were present but of substantially lower amounts. The reforestation economies were generally achieved at a smaller acreage, perhaps 50 to 75 acres, and the diseconomies of very small treatment areas were less than with the site preparation and intermediate treatments. The difference may derive from the relatively heavier labor intensity in the reforestation treatment with a correspondingly lower fixed cost for treatment initiation. In fact, the Douglas-fir reforestation equation did not display economies to scale at all but rather slight diseconomies to scale.

This finding is consistent with that reported by Thienpont and others (1976) in their study of timber harvesting systems in the Southeastern United States. They found that the degree of equipment intensification increased as the acreage of the harvest area increased. The relatively more labor intensive methods could apparently operate as profitably on small tracts as on larger ones.

The presence of several separate treatment areas in the same contract permits some economies to scale also. The treatment areas are not always immediately adjacent but they are no doubt closer to each other than to the contractor's base of operation. The number of multiple areas entered into the regression equations for all three site preparation equations and both intermediate treatment equations with the expected sign, that is, the cost per treatment area decreases as the number of multiple areas in the contracts increases *(table 7; fig. 7)*. For example, the treatment cost per acre for a Douglas-fir site preparation on a 75-acre area when there are two multiple areas is $59; the cost decreases to only $48 if there are five multiple areas.

The impact of the multiple area economies are not nearly as strong in the reforestation equations, however, just as the treatment area economies to scale were not. The multiple area variable only entered into one of the four reforestation equations and the magnitude of the cost impact was considerably less. The relatively greater labor intensity of the reforestation is probably also the cause of this result.

These equations provide an indication of the costs that may result from the maximum cutting area size established by the National Forest Management Act regulations (U.S. Dep. Agric., Forest Serv. 1979). Although the silvicultural treatments were not exactly coincidental with prior timber harvesting areas, they will probably be more coincidental in the future once the backlog of reforestation and timber stand improvement practices are completed.

Only a portion of the economies relative to scale are captured at the maximum cutting area size. For example, the average size of the Douglas-fir site preparation treatment areas in this study was 93 acres and the maximum cutting area size for the Douglas-fir type under the National Forest Management Act regulations is 60 acres. The estimated cost for site preparation of Douglas-fir areas 93 acres in size is $48 per acre. The estimated cost for areas equal to the maximum cutting size—60 acres—is 33 percent higher: $64 per acre. Similar results are apparent in the declining per acre cost curves *(figs. 3, 4, 5, 6)*. Part of the cost increase can be recouped by increasing the number of multiple areas in the same contract, but there is an economic opportunity cost to the cutting area restrictions.

Smaller cutting areas do offer benefits, such as greater wildlife diversity, less potential for soil erosion, and greater esthetic appeal. We do not infer from these results that these added benefits are either more or less than the estimated increase in treatment cost. Nonetheless, the estimated increase in silvicultural treatment costs is one of the consequences of the maximum cutting size regulations that must be considered.

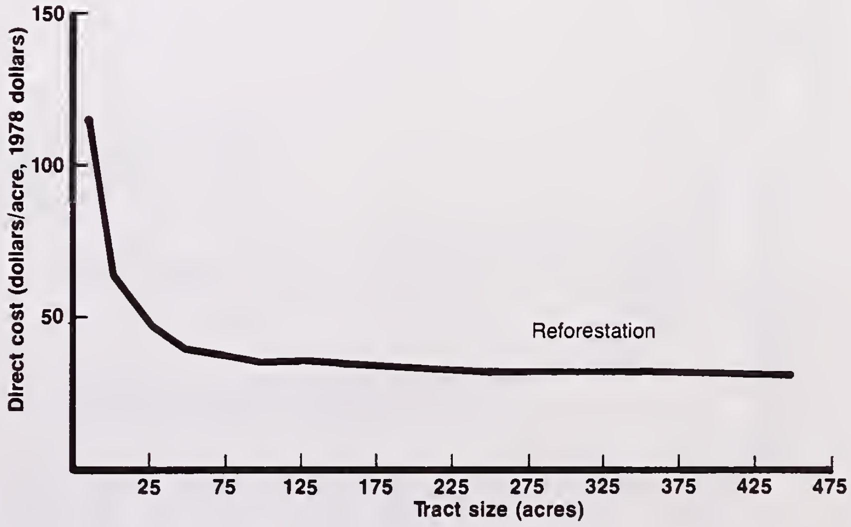

Figure 3—Direct treatment cost per acre for selected northern conifer treatment, by area size, as derived from regression equations based on cost per treatment area.

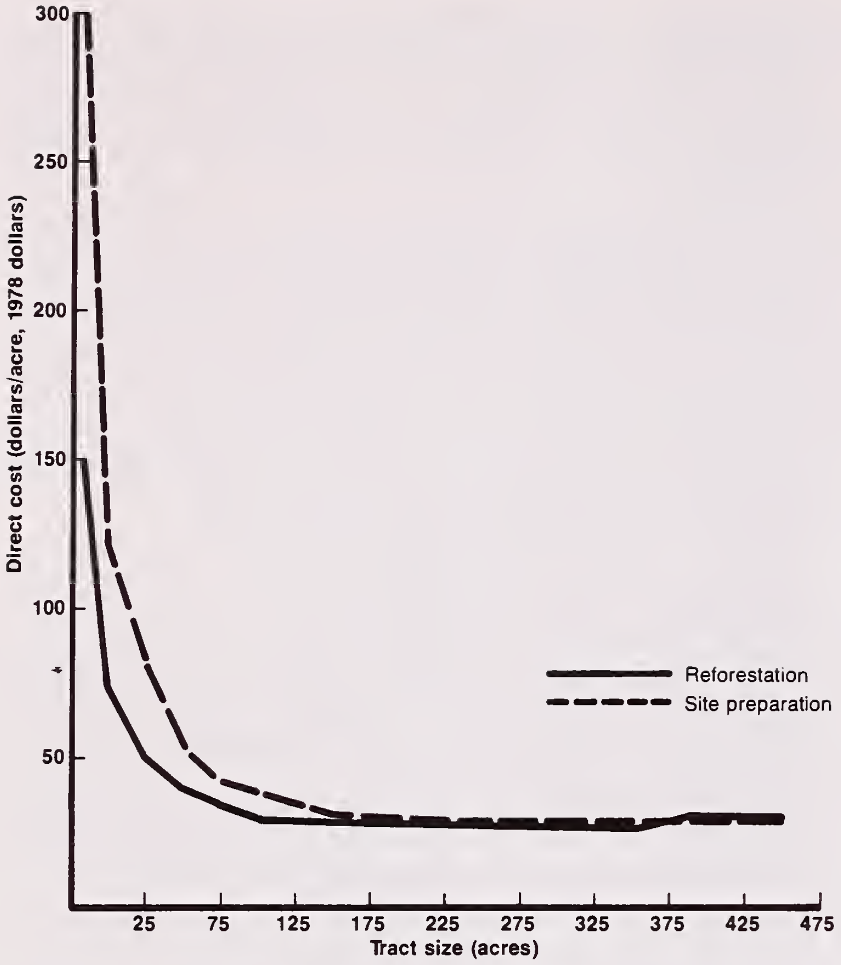

Figure 4—Direct treatment cost per acre for selected southern pine treatments, by area size, as derived from regression equations based on cost per treatment area.

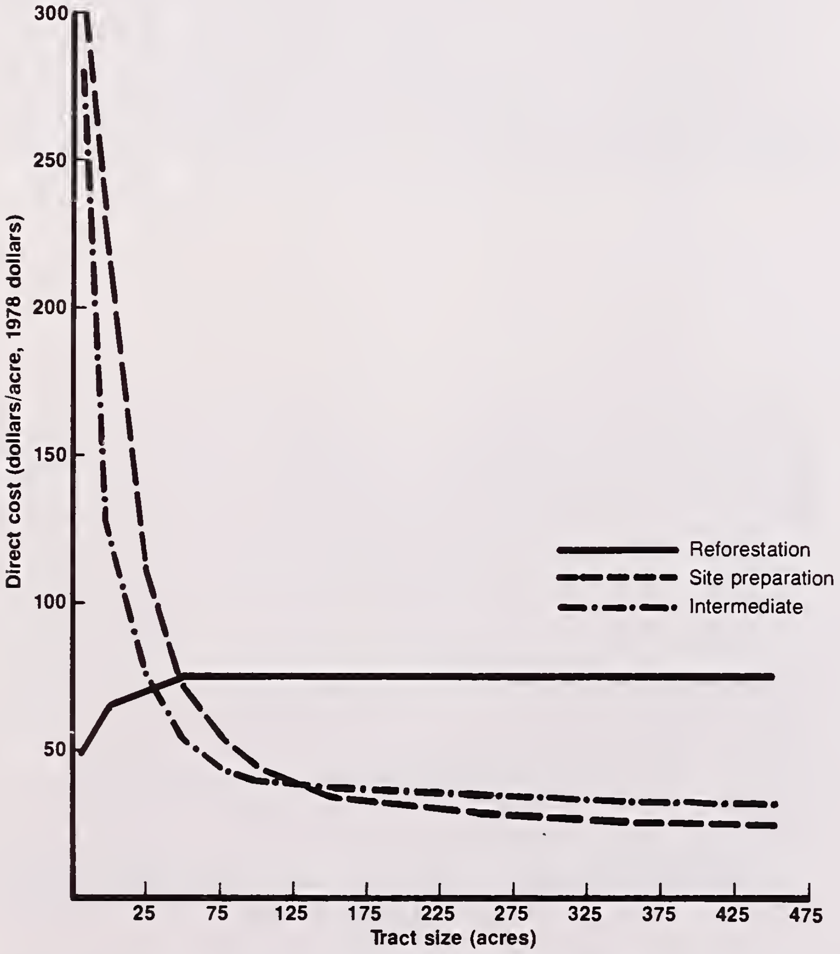

Figure 5—Direct treatment cost per acre for selected Douglas-fir treatments, by area size, as derived from regression equations on cost per treatment area.

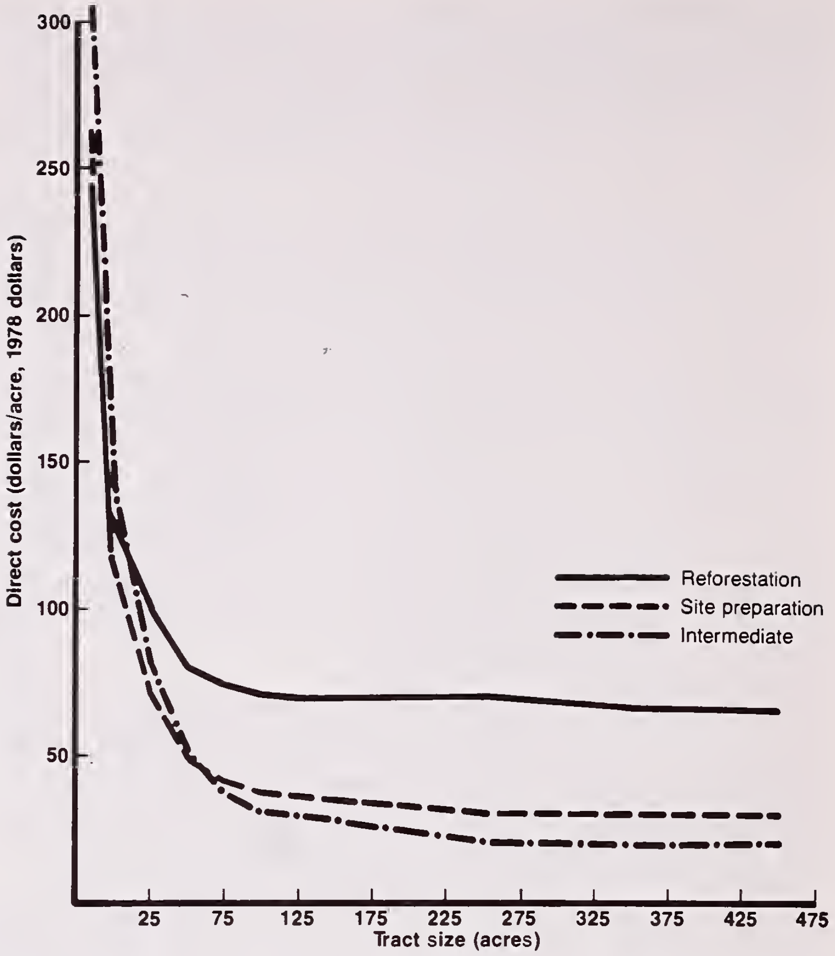

Figure 6—Direct treatment cost per acre for selected ponderosa pine and white pine treatments, by area size, as derived from the regression equations on cost per treatment area.

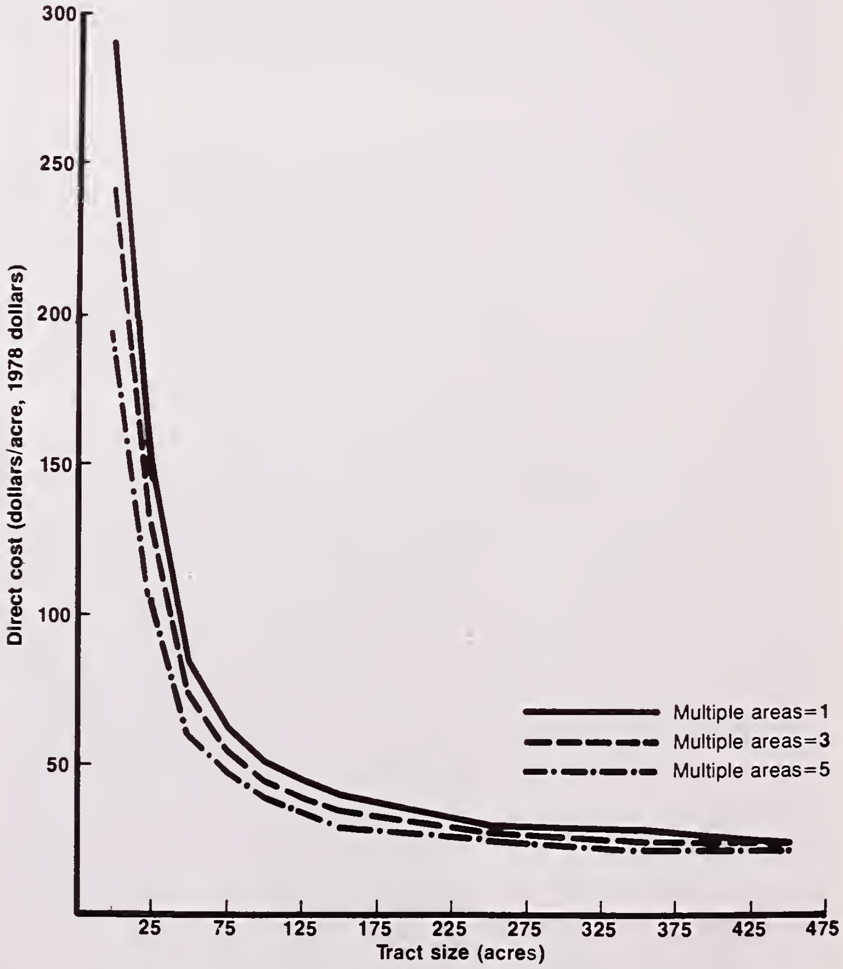

Figure 7—Direct treatment cost per acre for selected number of multiple areas for Douglas-fir site preparation, by area size, as derived from the regression equations on cost per treatment area.

CONCLUSIONS

This study of silvicultural service contracts for National Forest lands showed that the cost of silvicultural treatments or practices varied widely. Therefore, the cost averages derived from substantial aggregations should be used with care when budgeting for silvicultural programs. Budget estimates could contain a large error if the treatment composition in future programs differs significantly from past programs from which the cost averages were obtained.

From 1975 to 1977, real or inflation-adjusted costs rose by about 20 percent per year. Because the real cost increases were not uniform among the silvicultural treatments studied, financial return estimates should be recalculated more than has been commonly thought necessary in the past because their relative economic efficiencies will change.

Selected regression equations related the direct cost of silvicultural treatments to characteristics of the site and the practice. The significance of the equations was only moderate. That moderate significance, along with the large cost variance, raises the hypothesis that some of the cost variation may be due to the characteristics of the individual managers, rather than to the silvicultural objectives of the treatment or the site characteristics. If that hypothesis were true, it would imply that considerable effort should be put into development of more broadly applied treatment standards and into the sharing of the expertise of the more experienced silviculturists.

The regression results demonstrated that substantial economies relative to the scale of the treatment exist, where scale is expressed as the acreage of the treatment area. This was especially true in the site preparation and intermediate treatment practices. Economies were also found in the addition of more separate treatment areas to the same contract, again especially for the site preparation and intermediate treatments.

The regression results for the reforestation treatments also reflected some economies to the scale of the treatment area but not as much as the other two treatment categories. These lower economies to scale may be a reflection of the greater relative labor intensity of the reforestation treatment with the resultingly lower fixed cost. The reforestation treatments also showed considerably less cost savings from the addition of multiple treatment areas to the same contract.

The treatment areas are likely to be smaller as a result of the National Forest Management Act restrictions on the maximum size of cutting units than they were in this sample of service contracts from 1975 to 1978. Because of the smaller treatment areas, the real costs of the silvicultural treatments are likely to increase by at least 25 percent.

These results also support the hypothesis that the real cost of silvicultural treatments has risen—in this study by 20 percent per year from 1975 to 1977. The trend of increases of real cost and the anticipated decline in the size of treatment areas will combine to increase future silvicultural treatment costs on National Forest lands substantially.

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The direct costs of silvicultural treatments was estimated from service contracts awarded on National Forests throughout the United States in 1975-78. The mean direct cost (in 1978 dollars) of all treatments was $52 per acre and the mean, Forest Service (USDA) field time was 1 hour per acre treated. Real costs rose by about 20 percent per year from 1975 to 1977. This increase and the variability in cost indicate that budget preparation must consider the composition of planned silvicultural programs and that the financial returns for various treatments must be recalculated frequently, using updated cost estimates. Cost prediciton equations indicate that substantial economies relative to scale can be achieved by increasing treatment areas up to 75 to 100 acres. The smaller treatment areas likely to result from new cutting area regulations on National Forests could increase costs by more than 50 percent for some silvicultural practices.

Key words: site preparation, reforestation, cost predictions, cost variability, service contracts

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